

*Au Dr Fissiaux
Hommage de Pautant
19/1/13.*

OUR SATELLITE THE MOON

...LECTURE...

DELIVERED BEFORE

The Scientific Society of the University of Ottawa

BY

MR. L. E. O. PAYMENT.

OTTAWA:

THE OTTAWA PRINTING CO., (LTD.),

3 and 5 Mosgrove St.

1899.

Can
Pam
P

Payment, L. E. O.

INTRODUCTION.

In this essay it was not my intention to go into a complete exposition of all the phenomena connected with our satellite, giving the mathematical calculations by which the results mentioned are obtained, along with minute details, which in themselves are highly interesting, but on which the lack of time and space prevented me from dwelling. This precise and practical work falls within the province of the text-book and the Professor of Natural Sciences. The prime object was to present in a popular form the most important and striking facts relative to the moon, and thus attempt to arouse in the members of the Scientific Society of the University of Ottawa a love for the study of Astronomy, a science so replete with interesting and useful knowledge.

The members of the society, stimulated and encouraged in their efforts by the Fector, Very Rev. H. A. Constantineau, O. M. I., M. A., D. D., have shown a great and highly creditable zeal for the pursuit of scientific knowledge, and it was with feelings of pleasure that I accepted the honor of presenting the first essay before the Faculty of the University and the members of the newly organized society.

As it was wholly within the realms of the impossible for me to give the facts stated throughout this essay as results obtained by personal observation, I was obliged to have recourse to the pages of standard writers on astronomy. I chose as model and guide the volumes of the celebrated Camille Flammarion, whose extensive works on the natural sciences repay a thousand-fold the time spent in their perusal. I have dared to oppose Mons. Flammarion in his theory of heat on the surface of the moon ; I do so with all due respect to so eminent an authority, but I am supported in my assertions by many of the greatest astronomers of the day.

L. E. O. P.

Ottawa, Jan. 14, 1899.

THE MOON.

LECTURE DELIVERED BEFORE THE SCIENTIFIC SOCIETY OF THE
UNIVERSITY OF OTTAWA BY L. E. O. PAYMENT, '99.



THE first celestial body to occupy the mind of man and cause him to soar beyond the confines of his terrestrial home, was the pale attendant whose softened rays fall upon our planet during the hours when the god of day has disappeared to light the inhabitants at our antipodes. Astronomy, beginning with the study of the moon, has gradually extended its scope till to-day, the sun, the planets and the whole starry firmament, all come within its voluminous pages. And it is yet on its progress in the study of the universe. Led by the moon we turn heavenward and explore the wonderful work of the Creator.

There is no doubt whatever that the moon reigned as queen of the night many ages ere the eye of man was raised in admiration to contemplate its serene beauty. It is our nearest celestial neighbor and, as it were, belongs to us. Being our attendant planet it is like a distant province, an Australia to Europe. Its distance from us is only thirty times the diameter of the earth, and were 29 of our globes placed side by side they would form a bridge that would join us to our silent neighbor. According to our unit of measure the moon is distant only 238,840 miles. Not far indeed in comparison to the other celestial bodies; it is only $\frac{1}{317}$ of the distance to the sun, and $\frac{1}{10000}$ of that to the nearest fixed star. A telegraphic message would reach it in a few seconds; a flash of light produced here would be perceived on it almost instantaneously; while a train that could make the tour of the world in 27 days, would, at the same rate, reach our satellite in 38 weeks. When Mongolfier invented the balloon, the first idea that presented itself to the people as possible was the voyage to the moon. The impossibility of such a voyage is clear to everybody at the present day. The absence of a continuous atmosphere to the moon places the infeasibility of such an undertaking beyond a doubt; yet the expectation in the minds of the people at the tim

*Multiply the
again by
10000*

of Mongolfier was so great that a medal was struck showing the people of the moon with telescopes watching the aerial visitor upon its arrival. These people, it was supposed, would be terrified at the sight, and some ingenious poet wrote the following quatrain for the occasion :

Mais la frayeur est dans la lune,
Où le badaud et l'ignorant
Jugent l'aérostat errant
Une planète peu commune.

The diameter of the moon is found to be $\frac{1}{4}$ that of the earth, 2163 miles; its volume $\frac{1}{49}$ that of our globe and $\frac{1}{68000000}$ that of the sun. Its surface comprises, roughly speaking, an area equal to four times the continent of Europe, or to that of North and South America together. The mass of the moon is calculated to be about $\frac{1}{80}$ that of the earth while its density is $\frac{5.3}{10.5}$ that of our planet, or about $3\frac{1}{6}$ times that of water. The circumference at its equator is about 6795 miles.

The story of Newton and the apple is familiar to all. It is said that when he saw the phenomenon of the apple falling to the ground, he wondered why it was that the moon, which was shining brightly, did not act in the same way and fall to the earth also. Whatever credence can be placed in these traditions, it is certain that Newton set himself the task of solving a problem from which he evolved the laws of universal gravitation.

Galileo had already studied the question and noted that weight always produces on bodies the same effect in the same time whatever be their state of motion or rest. He had remarked that a body always acquires the same velocity per second whatever time may have elapsed since it began to fall, and that it always falls towards the earth at the same rate whether it has been dropped vertically or thrown horizontally.

A cannon-ball sent in a horizontal direction would never stop if it were not for the attractive force of the earth. It would proceed indefinitely in a straight line by the force of inertia, but gravity causes it to strike at a point lower than the mouth of the cannon. This point is lower by the same distance that the cannon-ball would have fallen directly from the mouth of the cannon without any initial velocity during the time the ball was travelling

to the spot which it struck. A strange phenomenon this, but it is proved by actual experiment.

This same law of Physics applies to the moon. Its movement around the earth is similar to that of a cannon-ball projected horizontally. Instead of continuing in a straight line it falls at each moment towards the earth just the distance which will make it describe an orbit approaching the form of a circle. And let it be remarked that at each moment it tends also to go directly on, but is drawn down as said above. The result is that it can never leave the earth nor can it fall upon it. The attraction of the earth acts precisely like a string at the end of which is fixed a weight. When the weight is set in motion it tends to fly off at a tangent, but is held by the string and cannot do so as it would should the string break. It is clear also that it cannot fall in since it tends continually to escape. It is thus seen that so long as the force of gravity exists the moon is bound to follow the earth in its wanderings through space, the earth in turn following the same laws with regard to the sun.

According to the principle that attraction is in inverse ratio to the square of the distance, the force drawing the moon to the earth is easily calculated, and it is found that it falls in $\frac{1}{16}$ millimetres in one second of time. It deviates that distance from the tangent line and thus makes its revolution of the earth. The attractive force of the earth is the agent which makes the moon describe its orbit, and it is easily understood that if that force were greater our satellite would describe its course in a shorter time, making our lunar months shorter also in direct ratio to the increase of gravity. The same law applies to the motion of the earth around the sun and our year would be shorter or longer in direct ratio to the diminution or increase of the attraction of the sun. Astronomy has fully proved this universal law, which is thus formulated: *Matter attracts matter in direct ratio of the masses and in inverse ratio of the distance.*

While the moon is making its revolution around the earth, the latter itself is revolving about the sun. The result of this movement of the earth is to make the moon's phases longer than the time of the moon's actual revolution around the earth. For, suppose the moon directly between the sun and earth. Now, should the earth remain still and the moon alone move, it would

*This is not the reason
it is the rotation of the earth that
is the cause.*

be back to the same relative position in exactly 27 days 7 hrs. 43 min. 11 sec. But the actual fact is that the earth moves many millions of miles during this interval with the result that the moon must travel much farther to be again placed directly between the sun and the earth. This distance is such that it takes the moon 2 dys, 5 hrs, and 52 seconds to travel over it. Hence our lunar months are increased to 29 days, 12 hrs, 44 min., 3 sec., almost 30 days. The motion of the moon from West to East may be considered as the first facts observed by ancient astronomers, and it served as the basis for the measurement of time and the invention of the calendar.

PHASES OF THE MOON.

We will now deal with the phases of the moon, and will first speak of these phenomena as observed by the ancients. Not having the artificiality of our modern society to monopolize their attention, they lived in closer communication with nature than we of this century. Shepherds for the most part, they laid the foundation of science on the solid rock of observation: they did not burn the midnight oil to study what others had observed; on the contrary, they observed and recorded what others study.

Astronomy, as I have said, is the most ancient of all the sciences, and the observation of the moon has furnished the first facts of that science, because it is the heavenly body that offers the greatest facility for study. As the shepherds of early ages, engaged even at night in tending their flocks, naturally turned to the moon for reference to the hour, it became the universal clock of night as the sun was that of day; and the means of measuring succession of days was furnished them by the regular recurrence of its phases. This last became a very important factor in early astronomy and deserves to be well noted.

During the course of a month the moon travels once around the earth in the direction from West to East. This is easily seen by comparing its position night after night with some particular star. It gradually recedes from the star and at the end of a month will return to it from the opposite side. The phases of the moon, however, are more easily remarked than this movement. When it has become freed from the rays of the sun and can be seen by the observer it shows a crescent with the concave edge towards the East, and as the sun shines on the West that side is illumined

and causes the round contour of the satellite to be seen ; this is the convex edge of the crescent. The horns are very sharp and the whole is clearly defined.

This crescent increases in size very gradually and in about 6 days attains the form of a hemisphere. The moon is then said to be in Quadrature which is commonly known as the First Quarter. At this time in its phases it can be easily seen during the day. Moving away from the sun, it assumes an oval shape, and in the course of 7 or 8 days it becomes perfectly circular and shines all night. This is known as Full Moon. It crosses the meridian at midnight and sets at sunrise. Being directly opposed to the sun it reflects upon us his light from the whole surface that is turned towards the earth.

The decline immediately begins, and the changes take place in an inverse order from what we have seen in its progress from New to Full Moon. There we saw it increase, now we shall see it decrease. From the large disc it becomes oval, then in Quadrature, finally crescent in shape, and gradually diminishes until it disappears when the sun shines on the side opposite to that presented to the earth. It is now between the sun and the earth and, being opaque, our side is left in darkness. Again, possessing no light itself, and having none to reflect, it is wholly invisible to the inhabitants of our planet.

When does the New Moon begin? The exact moment is very difficult to assign unless it should happen that at the precise moment when the moon is in conjunction, there should happen to be an eclipse. Should this latter occur we know the moon would have completed a revolution and set out immediately again. This, then, would be New Moon. The determination is of great importance to the Mussulmans as the appearance of the New Moon terminates their great annual fast, their Lent. They would, perhaps be the best authorities to consult on the matter. It is a greatly disputed point with astronomers, some saying that as long a time as 40 hours elapses from the moment of conjunction till it can be seen with the naked eye, and 27 before its conjunction. Amricus Vespucius stated the time to be much shorter in low latitudes.

A phenomenon that all must have remarked is that after the New Moon has appeared we see both the bright crescent and the remaining part of the moon in a dimmer light. The explanation

is that the earth reflects the light of the sun for the moon in the same manner as the moon reflects it for us. When the moon is in conjunction, that is, between the sun and the earth, the latter is in opposition with regard to the moon. Being in opposition it reflects the light of the sun in the same way as does the Full Moon when in the same position with regard to us. Were the moon inhabited, the people there might call it Full Earth. Moreover, the earth being much larger than its satellite must reflect much more light than does the moon. This phenomenon by which the whole body of the moon appears along with the crescent has received in English the very poetical designation of "The old moon in the new moon's arms".

This darkened outline of the rest of the moon can be more clearly seen by placing oneself where the rays of the illuminated crescent can be shut off, for instance, in the shadow of a house. By doing this the great spots on the surface of the moon can be easily observed. At its First Quarter, this darker outline disappears for two reasons : first, because the earth sends to the moon four times less rays than at New Moon ; and secondly, because the greater brightness of the moon prevents us from distinguishing it.

This remarkable phenomenon shows us the great reflecting power of the earth. In winter when the northern portion of the globe is covered with snow, the reflection is greater. Astronomers had come to the conclusion that some large body of land existed in the South on account of the great reflection that could not be produced by the immense southern oceans, for water absorbs the rays of light to a great extent. The discovery of Australia put this question beyond a doubt.

These phases of our silent attendant gave to the ancients their measure of time. The month is easily understood ; it is one revolution of the moon around the earth. The week, however, was determined by the phases themselves. A noticeable change takes place in the appearance of the moon every 7 days—New Moon to First Quarter ; First Quarter to Full Moon ; Full Moon to Last Quarter ; and finally Last Quarter to New Moon again. Thus was a period of 7 days established which became our present week. There was no other celestial body which acted so regularly and on which were produced such remarkable changes that could give the

ancients a standard for the reckoning of time. Families agreed upon certain phases of the moon to meet for their conversazione ; feasts were agreed upon in the same manner, and so important was it to know the precise time of the appearance of the New Moon that the people gathered together to watch for it, and the fact was promulgated by the High Priest with great ceremony and flourish of trumpets amid general rejoicing. All ancient nations : Romans, Greeks, Turks, Chinese, Peruvians, adopted this measure of time which seems to have been specially adapted to the crude civilization of those days.

As public administrations in early times found it necessary to assign dates in the future a calendar became a necessity. The problem of forming one engaged the attention of the best talents of the day. Meton in the year 423 B.C. by observation and calculation found that every 19th year the phases of the moon took place on the same day of the year. Thus, a full moon occurring on any particular day will be repeated on exactly the same day 19 years hence. This calculation is astray only one day in 312 years. Less correction was necessary than for our present calendar where one day must be added every fourth year, and dropped out every four hundredth. The Lunar Cycle is therefore a period of 19 years.

THE MOVEMENT OF THE MOON ABOUT THE EARTH.

The moon in its revolution around the earth describes an ellipse whose long axis differs in length very little from the short one. It therefore comes very nearly being a circle, and yet it must be remembered that this orbit is far from being so circular as that of the earth which approaches very closely to a perfect circumference. On account of this even slightly elliptical orbit, the moon continually changes its distance from the earth. This can be verified by noting the apparent difference in the size of its disc at various periods of its revolution. In the space of 15 days it varies about $\frac{1}{4}$ of its distance from us. This variation is perceptible, as I have said, in the decreased size of its disc, but particularly so, in the intensity of its attraction upon the earth, as evinced by tides of which I shall treat later on.

The movement of the moon in space is more complicated than is that of the earth. The most important peculiarities of this motion are the two following :

I. The orbit of the moon around the earth is not in the same plane as that of the earth's around the sun. If it were there would occur an eclipse of the sun at each New Moon and one of the moon at each Full Moon. It is not thus because the plane of the moon's orbit is inclined 5 degrees to that of the earth's. Even the points of intersection of these two orbits do not remain fixed, but travel around the Ecliptic once in $18\frac{1}{2}$ years.

II. The inclination itself of this orbit varies. The mean inclination is $5^{\circ}, 8', 48''$ but it makes as small an angle as $5^{\circ}, 0', 1''$ and one as great as $5^{\circ}, 17' 35''$, going from the smaller angle to the greater and back again to the smaller in the course of 173 days.

There are many other motions upon which I shall not dwell, but it is a satisfaction to know that though the Great Ruler has given our silvery satellite such variations in movement He so governs them as not to prevent it from performing with regularity its kind offices to man.

It is wonderful to note that the study given to the moon has brought to light more than 60 different irregularities in its motion. When we see the great penetration which man has shown himself to possess we cannot but conclude that his intelligence proceeds from the One who framed the universe and who permits him to have a glimpse of the vastness of His intelligence who conceived the wonderful harmony and beauty of all He has made.

To have a complete idea of the motion of the moon in space we must consider that if the earth were stationary, the moon would describe an ellipse about it and close it where it started. But the earth is itself in motion, and consequently the moon cannot describe this ellipse and return to the point whence it set out. Its path is really a sinuous line crossing and recrossing the orbit of the earth around the sun, and this line is so prolonged on each side of the earth's orbit that the two orbits practically coincide.

Thus the initial motion given the earth carries it through space. The sun itself is probably describing an orbit around some other celestial body; the earth follows the sun, revolving about it in a fraction over 365 days; the moon follows the earth going around it once in 29 days and a few hours; the stars have motions of their own, and probably are surrounded by globes like ours; and all is guided by the same being whose power is beyond the

conception of human intelligence. The mind of man is amazed at the contemplation of these wonders.

We have thus far seen the distance, the size, and the movements of the moon. We shall now touch upon the subject of its weight; this will give us its density and the force of attraction on its surface.

To the uninitiated the question of weighing the moon will appear preposterous, but the following method adopted by scientists will be reasonably clear to those who have made even a superficial study of Astronomy or Physics.

The moon causes the Tides; that is, twice a day the waters of the sea rise above their level owing to the attractive force of the moon, and fall as soon as the position of the moon is so shifted that it no longer exercises this attractive power. Now, by measuring exactly the height of the water thus elevated, and knowing its quantity and weight we can find the force necessary to raise it. From this the weight of the moon can be deduced.

Here is another method. The moon in its revolution is sometimes before the earth. At these times our satellite accelerates the motion of our planet. Again later on it is behind, and then it retards the motion of the earth. The effects of this at the First and Last Quarters is to make the sun apparently move aside a distance of $1/290$ part of its diameter. Since the moon is the cause of this displacement its mass can be calculated and, this being given, the weight can be easily found.

By these methods it has been ascertained that the weight of the moon is 81 times less than that of our globe. As its density is $1/6$ that of our planet objects on its surface weigh 6 times less than here. A man tipping the scales at 240 here would be only a featherweight of 40 pounds on the moon. Should he be placed upon its surface and retain his strength, he who could lift 500 pounds here would with the exercise of the same force raise 3000 there. One who could jump 15 feet here could leap 90 on the moon with the same ease.

This remarkable lightness of matter has had great effects upon the moon's physical features, for natural forces such as pressure of gas, explosions, and volcanic energy remaining the same as here, have caused mountains of enormous heights to be tossed up on its surface. Andes have been piled upon Rockies and capped

with Himalayas upon the face of the body that looks down so tranquilly upon us in the soft nights of summer.

And let it be remarked that were the moon as large as the earth its diameter would be increased, and, as attraction varies as the square of the distance, a body at the surface of the moon would weigh only $1/90$ of what it does on the earth. A person weighing 180 pounds here, would have an avoirdupois of 2 pounds there. The same effort we make to jump 5 feet would launch us to the height of 450. A dangerous place to play leap-frog, I hear you say; but we must remember that we would fall also with only $1/90$ the force, a fact that would counterbalance matters.

The following table gives the comparative weights of bodies on the sun and the different planets :

Sun.....	27.474	Uranus....	0.883
Jupiter...	2.581	Venus.....	0.864
Saturn....	1.104	Mercury...	0.521
Earth....	1.000	Mars.....	0.382
Neptune..	0.953	Moon.....	0.164

We here see that bodies weigh less on the surface of the moon than on that of any other planet in the solar system.

PHYSICAL FEATURES OF THE MOON.

Not till he knows the Author of all being will the thirst of man for knowledge be satiated. His search is unending, and it is not strange that the moon has been a problem which he has been continually attempting to solve. It would indeed be a great satisfaction for us to know whether or not the moon is inhabited. We are much like children who throw away the toys they have to grasp for new ones. We long for knowledge of this far off world while there are immense tracts of our own globe as yet unknown. Neither the North nor South Pole of our world has yet been visited by man. It is true Nansen crossed the Arctic Ocean but he has not located the exact spot where is situated the North Pole; while no successful attempt has ever been made to know anything about the southern extremity of the imaginary axis of the earth. The intensity of the cold prevents our attaining these points on the earth, and the same cause along with the tenuity or absolute lack of the atmosphere renders a voyage to the moon beyond possibility. We are actually prisoners surrounded on all sides, as it were, by an invisible wall of cold the intensity of

which is beyond imagination, and from this prison we can soar only in thought to the celestial regions beyond. Where is all our boasted freedom? We can go only a few miles beyond, and cannot know even all of, our own little world.

From ancient times the moon has been looked upon as receiving its light from the sun and reflecting it to us. This theory was supported by Thales, Anaxagoras, Anaximander and Empedocles. The last mentioned philosopher sustained that its heat on account of reflection reaches us in a very much diminished state, indeed almost a minus quantity. This has been upheld by Lord Rosse who says the heat of the moon is $1/80,000$ of that of the sun. Proclus held that mountains and valleys along with peoples and cities existed upon its surface. Anaxagoras speaks of mountains and valleys but makes no mention of inhabitants. Pythagoras maintained it was a world similar to ours but inhabited by animals of much greater size and strength than those of the earth. He stated that plants were proportionately greater than ours, and held this proportion to be as 1 is to 15; so that instead of man's being 6 feet in height, he would be 90. Our 40 foot trees would correspond to those of the enormous height of 600.

It was not, however, till 1609 when Galileo made use of the telescope to study the moon that we have any definite idea of the nature of its surface. He found its face to be very rugged, having great mountains and very deep valleys. The first map of the moon resembled in a marked degree the human face, as the spots seen by the naked eye make it resemble the eyes, nose, and mouth of a man.

We can see the principal spots with the naked eye, but the telescope reveals an immense number entirely invisible to us without its use. The most favorable occasion to make an observation is when the Full Moon crosses the meridian at midnight. The cardinal points of the compass correspond to those of the earth as we represent it to ourselves, the upper portion being North; the lower, South; the left side, East; and the right, West. When looking at it, however, through a telescope the image is *inverted* and it is thus that all maps of it have been drawn. These maps, it is admitted, are made with much greater accuracy than are those of our globe; for it must be confessed that our maps,

particularly of Africa and Asia along with the northern and southern portions of the globe, are anything but complete.

Helvelius drew the first map of the moon in 1647, and was so scrupulously careful to have it exact that he engraved it himself. The nomenclature he adopted was that of our oceans, mountains, lakes, and cities. He transformed the moon into a second earth. He had intended to use the names of important men, but feared to alienate his friends by not giving their names such prominence as they might expect him to do. Father Riccioli S. J. with the characteristic fearlessness of the Jesuits, boldly adopted the plan rejected by Helvelius : his map is the one best known.

The topography of the moon shows large gray spots and darker ones. The former are mountainous districts, while the latter are called seas.

On the left side of the map below the equator, that is in the N-W, we find the *Mare Crissium*. We must be on our guard as to the meaning of *Mare*. By this term is not meant ocean of water. This name was first given by early astronomers, but modern science has proved what they termed *Mare* to be nothing but vast plains with a possibility, as we shall see, of their containing a small and imperceptible amount of as yet unevaporated water. This *Mare Crissium* can be seen shortly after the New Moon, but it is the first to disappear after this phase.

A little to the N-E of this is found the *Mare Serenitas*, a large spot of an irregular oval form.

Somewhat to the S-W of this latter is found the *Mare Tranquilitas* ; its borders or shores are less regular. There is a gulf on its eastern side known as the *Mare Vaporum*.

The *Mare Tranquilitas* is divided into two branches which have been called the legs of "the man in the moon." The western one is known as the *Mare Fecunditas* and the eastern as the *Mare Nectaris*.

To the far North is found what has been termed the *Mare Frigoris*. It corresponds to the Arctic Ocean of our globe.

Between the *Mare Serenitas* and the *Mare Frigoris* is found a lake known as *Lacus Mortis Somnii*, a ghastly name indeed.

The bogs known as the *Mare Corruptionis* and the *Mare Nebularum* occupy the eastern side of the *Mare Pluviorum* of which the northern boundary forms the *Mare Iridium*.

All that part of the moon situated in the East is dark. The edge of an immense spot is confounded with the luminous portion of the disc. The northern part of this spot is made up of the *Mare Pluviarum*, already mentioned, which gives rise to the gulf known as *Oceanis Tempestatum* in which can be seen the great craters Kepler and Aristarchus.

The more southern portion of this "ocean" near the centre is given the name of *Mare Nubium*, while nearer the eastern edge it is called *Mare Humorum*.

About $\frac{1}{3}$ of the disc of the moon is covered with these spots, but the observer can see with the naked eye the great crater *Tycho* which, shining very brightly, reflects the rays of the sun for a great distance around.

The relative size of the clear parts, that is, the mountainous regions of the moon, have been measured very carefully and found to be, with regard to the spots, in a proportion expressed by the numbers 332 to 121.

It requires a telescope of but very weak magnifying power to show the rugosity or wrinkles in the surface of the moon. The famous mountain *Tycho* found in the south is the greatest elevation on the surface of our satellite. It possesses an enormous crater the mouth of which is fully 60 miles in diameter. At the moment of Full Moon, *Tycho* shines with such intensity that the eye is dazzled, and cannot observe the geological phenomena of the crater. Mount Copernicus is another possessing great beauty and interest. The diameter of its crater is nearly 59 miles. Among other mountains may be mentioned Leibnitz whose height is 7610 metres (one metre being 39, 37 inches); Doerfel, 7603 metres; Newton, 7264 metres, and many others. There are mountains so situated that their summits never lose sight of the sun; they have been called the Mountains of Eternal Light.

The most remarkable feature of these mountains is the size of their craters. The largest craters of terrestrial volcanoes are of no consequence in comparison to them. Etna's has a diameter of but 3,600 metres, and the largest on earth measures only 70,000 metres; while in the moon we have Petau with a diameter of 150,000 metres, Sacrabosco, 160,000; Schickard, 200,000; and Clavius, 210,000 metres. Yet the moon is 49 times smaller than the earth!

The mountains of the moon are, relatively to its size, much higher than those of the earth. There are many peaks that reach the height of 4 miles, and Doerfel and Leibnitz equal the 470th part of its diameter. Our highest peak, Everest, in the Himalayas is but $5\frac{1}{2}$ miles, only the 1443rd part of the terrestrial diameter. These mountains have been thrown up by gigantic eruptions. The geological formations in the moon have been carried on in the same way as those of the earth; and as the specific gravity of matter is less, and the physical forces of nature remain the same, it was possible for the expansive force of the gases to raise these enormous masses of rocks to such stupendous heights.

Astronomers believe that at some time there actually were oceans on the surface of the moon, and that they occupied the low parts or spots, as we have previously called them. Now, as the force of gravity is much less than that of the earth, matter in the moon has less density than here and is consequently more porous. It is contended from this fact that these oceans were gradually absorbed by the moon, and that probably there may still exist moisture in the bottom of the low-lands. Some maintain chemical combination instead of ordinary absorption.

The map of the moon which has been described is only of one side of it—one hemisphere—for that planet always presents the same face to the earth. No human eye has ever seen nor ever will see, its opposite hemisphere, as it travels around the earth just as a balloon would in making a similar voyage, always presenting the same face to us. But it does turn, that is, once on itself during its revolution; otherwise we should see every side of it.

ATMOSPHERE OF THE MOON.

We have seen that the moon presents striking similarities to our globe in its geological formation. Let us now inquire if it possesses an atmosphere. Should it have one, there would be a possibility of animal and plant life resembling ours to exist upon it. The closest study of the moon has not been able to discover the existence of an atmosphere ; for should it exist there would at times be phenomena similar to our clouds. No lunar clouds have ever marred the success of an observation : the moon always presents the same clearness of surface and none even of the slightest details have ever been obscured by a passing cloud. The complete absence of twilight, a necessary attendant upon the atmosphere, seems to prove beyond question that if any atmosphere exists does it is of extreme rarity and could not therefore support life such as we know it ~~exists~~ upon the earth.

Another proof of the absence of an atmosphere is given when the occultation of a star takes place. The star disappears suddenly and reappears as suddenly on the opposite side. Mathematical calculation can ascertain the exact time it should take the moon to travel the width of its disc. Now, should there exist an atmosphere the rays of the star by refraction would be slightly diverged and the time of occultation varied. There is, however, found to be an exact correspondence between the result of the calculation and the time taken for the occultation. This proves that no refraction has taken place, and consequently that no atmosphere similar to ours exists on the surface of the moon. Moreover, when the moon passes between the sun and the earth no penumbra is apparent. The shadow is clear and distinct. The existence of an atmosphere would cause this phenomenon to appear. Spectrum analyses too show that the moon reflects solar rays alone just as a mirror would, for the rays coming from the moon are precisely the same as those coming from the sun

proving that the moon as a luminary sends forth no light particularly its own.

Despite these proofs some astronomers, among them the celebrated Camille Flammarion, maintain with a large number of convincing arguments based on observation, that there may exist an atmosphere but one of extreme tenuity. They say the height of the lunar atmosphere is 20 miles and its density at 0 degrees is $\frac{1}{10000}$ of the terrestrial atmosphere. "This atmosphere" says Flammarion, is not insignificant and can exist." Now, the conditions of habitability on the moon are very difficult. Having no atmosphere, or a very tenuous one at most, there is no celestial vault, no azure sky, no clouds, nothing but an unfathomable abyss perpetually illumined by the stars that shine day and night. The rays of the sun reach it with as great intensity as they do the earth, but their effect is quite different. Passing, we may say, through no atmosphere, they fall with a bright glare that would be intolerable to human beings who have the advantage of clouds at times and whose day is no longer than 12 hours, while the moon's days are of 360 hours' duration. Moreover the rays cannot be diffused: wherever they do not fall it is black darkness. As far as heat is concerned, we cannot see how, in the absence of an atmosphere to collect it, it could ever rise to any great degree, any more than ~~the~~ does on the summits of our highest mountains which are covered with perpetual snow. Even whatever amount of heat there is would have to be collected during the 15 days the sun is shining upon one side of it; and the cold must be, according to some authorities fully 200 degrees below zero in the absence of sunlight.

TIDES.

The waters of the ocean rise and fall periodically: these motions are known as the rise and fall of the tide. This phenomenon was such an unsolvable problem for ancient astronomers that it was known as *the grave of human curiosity*. There is, however, such a correspondence between the tides and the revolution of the moon around the earth that a few even of the ancient astronomers, among them Pliny and Plutarch, came to the conclusion that they were produced by the moon. But the fact had not been demonstrated and many denied it. Galileo and Kepler never believed it. It was Newton who undertook the mathematical proof of the fact, and Laplace who proved beyond the possibility of reasona-

ble doubt, that the tides are caused by the attractions of the moon and the sun.

The waters of the globe are spread over it from North to South in those two great basins known as the Atlantic and Pacific oceans. The other oceans are but continuations or parts of these. Now, these waters are free to move, and do so on account of the attracting force of the moon. But they are not equally attracted in all parts. The portions of the ocean situated at the Equator immediately under the path of the moon in its revolution around the globe, are more attracted than are those at or near the poles. As a consequence the former rise to a greater height than the latter and at the poles themselves no tide would occur even if it were not prevented by the oceans of perpetual ice.

The moon raises the waters beneath it and forms what we call tides. This is easily understood. But that it should cause at the same time an equal elevation on the *opposite* side of the earth is not quite so clear. The explanation is this: the moon has greater attraction for the solid portions of the earth than for the waters on the opposite side, being closer to the former by the distance measured by the length of the diameter of the earth, and as a result draws it more than it does these waters. The waters on the opposite side are therefore, as it were, left behind, and in their effort to separate from the earth since, this tends to leave them, they accumulate and form a tide. At New Moon, the sun and moon act together to produce a greater effect, and at Full Moon they act similarly, each on its own side, to produce an analogous result, so that at the periods of New and Full Moon the tides are at their maximum height.

Tides are of two kinds, Spring and Neap tides. The former are caused by the joint action of the sun and moon at the periods known as New and Full Moon, for then only are the earth, sun, and moon in a straight line. When the moon is in its First or Last Quarter the sun and moon act at right angles and the result given by a calculation of the parallelogram of forces is greater at this angle than either force acting alone but much less than both acting together. The tide consequently is lower than the Spring tide, and is called Neap tide. It will be noted that the sun has a lesser attractive force on the earth than has the moon, the latter more than compensating for the weakness of its attraction by its

proximity. The relation of the forces are as 2 is to 1 in favor of the moon.

To write a complete explanation of the heights and terms of the tides would be to treat of phenomena which more nearly concern the earth; while our subject treats only of the influence the moon exerts in producing them. I have for that reason confined myself to the matter in hand leaving to the student of Physical Geography the explanation of the effects of the tides on the earth. But I cannot overlook another view which has been taken on the probable action of the moon upon our atmosphere as well as upon the molten mass at the centre of the earth.

Concerning the influence of the moon upon our atmosphere which is like a great ocean encircling the globe, M. Camille Flammarion says there is a possibility of the existence of atmospheric tides, but that the theory cannot be verified. The variations of barometric pressure without any assignable cause of great importance seem to his mind to indicate the existence of these tides in our atmosphere. But he touches a more important point when he states the possibility of tides of the fluid mass at the centre of our globe. So convinced has been Mr. Perrey, Flammarion's colleague in the Academy of Dijon, of the truth of this theory that he set himself the task of ascertaining the dates of the great earthquakes that had taken place throughout the world. He found they corresponded to a great extent with the periods of New and Full moon, as well as when the moon is at its perigee, that is, nearest the earth. These observations tend to prove the theory of the existence of tides in the molten interior of the earth.

INFLUENCES OF THE MOON.

If *Vox populi vox Dei* were a law of Physics, one might say the moon exercises great influences on almost everything earthly. Many animals, plants, eggs, grains and almost everything else are supposed by some to be governed in their actions to a great extent by our celestial neighbor. We shall attempt to clear up a few of these points.

As far as the moon's action on plants is concerned the popular idea is totally at fault. Young plants freeze in the light of the April moon. This cannot be denied, but it is wrong to attribute it to the rays of the moon. The great English physicist, Wells, has shown that objects may acquire at night a temperature wholly

more we know of the moon's influence

different from that of the surrounding atmosphere. Small pieces of cotton, eider, etc., have been found to possess a temperature of 6, 7 and even 8 degrees centigrade below that of the atmosphere immediately in contact with them. Vegetables act like these materials and may freeze solid while exposed to a temperature even several degrees above the freezing point. This phenomenon occurs only when there is calm moonlight, and is totally absent when the moon is obscured by clouds. We have the example of dew and hoar frost which are produced in a similar way. The reason of this occurrence is probably found in the fact that clouds prevent the heat accumulated during the day from escaping to the higher atmosphere, and as a result there is greater heat on the earth. In this case the plants could not freeze, nor could we have dew nor hoar frost.

The most important question however is that of the moon on the weather. Now, the only means by which the moon could influence our weather would be by heat or light. The action of these two agents can in no way explain the sudden changes of weather that are attributed to the influence of the moon. Their action is too weak as we have already shown in our observations with regard to heat; and when we consider that the light of the moon is 300,000 times weaker than that of the sun, we can see no solid argument on which to base any statement that the moon has any material influence on the weather. Observations, moreover, prove that no credence can be placed in the popular theory on the subject. Arago found that the maximum of rainy days in Paris occurred at First quarter and Full Moon. Schübler found the same result for Stuttgart, but Gasparin found that the contrary held true at Orange and Poitevin, while still another result was obtained at Montpellier. So that the weather seems to depend on conditions over which the moon has no control. Moreover the phases of the moon never occur more than 7 days apart, so that a change in the weather cannot take place at any very great length of time from a change in the moon. This is probably the reason people have connected the idea of change in the moon with that of change in the weather. No data from which an exact correspondence in the changes of the weather, and those of the phases of the moon have ever been gathered to maintain the theory, and it may be set down as a popular fallacy

along with so many others that have been dissipated when the search-light of science has been turned upon them.

ECLIPSES.

When the ancients, before the explanation of eclipses was made clear to the world, saw the sun or moon gradually disappear from their sight, they believed, and we cannot wonder at it, that dragons or evil spirits were attempting to destroy the harmonious order of the universe. Man in a low state of civilization or education is naturally of a highly superstitious temperament; and we can readily see why, in the absence of a rational explanation of the cause of eclipses, our predecessors accepted any explanation which their benighted intellects might suggest.

The story of how Columbus worked on the fears of the inhabitants of Jamaica is familiar to all. Wanting food and not being able to procure it from the natives, he threatened to deprive them of the light of the moon. Knowing of the approaching hour of an eclipse he could make that threat with impunity feeling certain that his command (?) would be obeyed. The eclipse began, and the natives, terrorized at his seeming power, supplied him with the required sustenance for himself and crews.

Eclipses, as is generally known, are produced on the moon when this body is in opposition, that is, at Full Moon. If the shadow of the earth fall upon the whole moon there is produced a total eclipse, upon a portion only of its surface there results only a partial eclipse. That the shadow of the earth may reach the moon is shown by the fact that it stretches out into space like the tail of a comet to the distance of about 860,000 miles, while, in round numbers the moon is only 240,000 miles from the earth. The moon in its revolution around the earth, coming within that "tail," is eclipsed totally or partially, as the case may be.

Eclipses of the sun take place only at New Moon, when this body is in conjunction, that is, comes directly between the earth and the sun. These eclipses, unlike those of the moon, can be seen only in certain parts of the earth. On the contrary, eclipses of the moon, are seen at the same time from every part of the earth which faces that body.

Ancient astronomers who knew not with as great precision as we, the movement of the moon in space, could not predict eclipses of the sun. But they could foretell those of the moon with a

great degree of accuracy basing their calculations on the fact that the eclipses of the moon repeat themselves in periods of 18 years and 11 days which may be called the cycle of lunar eclipses. It was sufficient for them to know the dates of former eclipses to be in a position to predict future ones.

With the science of Astronomy as far advanced towards perfection as it is at the present day, it is possible to foretell for centuries ahead, or calculate for ages past, the precise moments at which eclipses of either sun or moon will or did occur with the addition of all details they will or did possess at any particular point on the earth.

To illustrate the exactness of astronomic calculation the following will not be useless. Herodotus tells us of a battle which was to take place between the Lydians and the Medes. Just before the opening of the combat a total eclipse of the sun took place which so terrorized the would-be combatants that they desisted from their purpose. The historian does not give the exact date of the event, and subsequent authors have fixed it indefinitely from 626 B.C. to 593 B.C. Astronomers have calculated that eclipse to have taken place on the 28th May 585 B.C. and thus settled the controversy on the matter.

There is a strange phenomenon that presents itself to the student of eclipses. Since the moon must be in direct opposition to the sun in order that an eclipse of it may take place, how is it that at times we can see both sun and moon above the horizon during an eclipse of the latter? At first sight this seems paradoxical, but the fact is explained by refraction: the rays of both bodies are diverted by our atmosphere from their direct course and reach the eye, permitting us to see them while in reality one or both, may be below the horizon.

I have now said enough on the subject of lunar eclipses to give at least some idea of how they occur and the manner in which the time of their appearance is calculated. It now remains to treat a little more fully of the eclipses of the sun. These are of three kinds, partial, annular, and total. They are caused, as has been said, by the interposition of the moon between the earth and the sun. Since the moon is not large enough to hide the whole face of the sun, except from those immediately within the shadow which it casts on the earth, and from these only under

given circumstances, there is partial eclipse of the sun. I have said "not large enough." This is saying too much. It is large enough when the eclipse takes place at the moon's perigee, that is, when it is nearest the earth. A foot-ball would cause an eclipse of the sun for one person if it were placed within a few feet from his eyes. When the moon is at its perigee there is total eclipse of the sun for regions within the shadow of the moon. For those immediately outside the shadow there might be annular or partial eclipse, while for the most remote parts of the earth, those coming outside of the shadow, there would be no eclipse at all.

An annular eclipse takes place when the moon is interposed between the sun and earth and far enough away from us, that is, at, or approaching its apogee, to permit the outer rim of the sun to be seen. This rim resembles a bright shining ring, hence the name annular.

I have said a solar eclipse may be total for one region and annular for another. This very rarely occurs but may happen when the apparent diameters of the sun and moon are nearly equal, because the moon is not at equal distances from all parts of the earth.

And now I have done. My essay has proved to be no doubt very lengthy to some, and perhaps uninteresting to many. Its length, however, must be attributed to my theme, so vast in its comprehensiveness. Its lack of interest must be due to my poor treatment, for certainly few themes there are to vie in interest with that which epitomizes our knowledge of

"That orb'd maiden, with white fire laden

Whom mortals call the moon."
